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Research Article

Let's talk aliens - Stakeholder perceptions of an alien species differ in time and space

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Abstract

Humans play an integral role in biological invasions, from aiding introductions of alien species to experiencing their impacts and holding the ability to manage them. The importance of understanding the dynamics of stakeholders' perceptions on alien species is therefore increasingly recognized. In this study, we used anonymous online surveys to contrast recreational anglers' perceptions towards European flounder (*Platichthys flesus*, Linnaeus, 1758) in Iceland, where it is classified as a potentially invasive species, to the perceptions prevailing amongst recreational anglers in the species' native range. We furthermore explored potential temporal changes in the perception of Icelandic recreational anglers. Our results indicate that Icelandic recreational anglers have a highly negative perception towards the European flounder, while in its native range, recreational anglers have positive perceptions towards this species. In Iceland, we have furthermore detected a significant change towards less negative perceptions between the surveys administered in October 2019 and March 2023. Finally, we compared the results of the online surveys and novel, conservation culturomics tools to further explore stakeholder perceptions and public interest in Iceland. The comparison highlighted some limitations that should be considered when using culturomics in very small societies or for small languages. For example, the text mining approaches on newspaper articles and social media conservations detected neutral perceptions in the communication to the public and within the targeted stakeholder group via social media in contrary to the perceptions detected in the online surveys. Moreover, we detected short-term peaks in the public's interest in European flounder and potential drivers of those peaks using Wikipedia pageviews but Google Trends provided mixed and unreproducible results. Overall, our study highlights that stakeholders' perceptions towards an alien species as well as the public's interest in it vary over time and space, though the drivers of these changes are often difficult to identify.

Key words: Angling community, biological invasions, communication and outreach, conservation culturomics, culturomics, digital data, European flounder, *Platichthys flesus*, recreational angling community, stakeholder perceptions, surveys

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Introduction

Biological invasions are widely accepted as one of the main drivers of biodiversity loss globally (Caffrey et al. 2014; Bellard et al. 2022; IPBES 2023). Invasive alien species (IAS) are causing a wide array of severe environmental and socioeconomic

impacts in the invaded areas (Hawkins et al. 2015; Bacher et al. 2017; Diagne et al. 2021). While early research on biological invasions focused mainly on ecological aspects, it is increasingly recognized that their human dimensions need to be considered (Shackleton et al. 2019a). Humans play a crucial role in every step of the invasion process, from driving both intentional and unintentional introductions, to experiencing the impacts of invasive species, and having the ability to prevent future invasions and manage current ones (Pyšek et al. 2020).

It is important to understand the perceptions of stakeholders towards IAS, while recognizing that these might drastically differ between groups (Garcia-Llorente et al. 2008; Jefferson et al. 2015; Shackleton et al. 2019b). Stakeholder perceptions are essential to assess social impacts caused by IAS and can aid the prioritization of resources dedicated to management (Shackleton et al. 2019b). Furthermore, they enable managers to understand and mitigate opposition to management actions prior to implementing them (Novoa et al. 2018). Thus, awareness of biological invasions is an important driver of stakeholders' perceptions and support for management (Verbrugge et al. 2013; Courchamp et al. 2017; Novoa et al. 2017). Increasing public awareness requires good communication and outreach efforts that go beyond the classical model of top-down provision of information (Nisbet and Scheufele 2009) by initiating genuine dialogue between experts, stakeholders, and the public (Courchamp et al. 2017).

Traditional tools to document perceptions include surveys and interviews. These tools have been used to assess the perceptions of the general public on specific alien species and their management (Verbrugge et al. 2013; Novoa et al. 2017; Luna et al. 2019), as well as the perceptions of specific stakeholder groups (Garcia-Llorente et al. 2008; Trenouth and Campbell 2013). However, traditional tools require significant resources, have a limited geographic reach and potential interviewer and respondent biases, which has encouraged the development of novel approaches (Scharkow and Vogelgesang 2011; Di Minin et al. 2015). The newly established field of conservation culturomics uses digital data (Ladle et al. 2016), sourced from various platforms such as web pages, video-sharing platforms, news media, social media, and digital encyclopedias (Correia et al. 2021). These novel approaches are considered promising for the field of invasion science (Jarić et al. 2021) as they have the potential to provide valuable data (Ladle et al. 2016), especially in combination with other sources (Toivonen et al. 2019). Conservation culturomics techniques have been applied, for instance, to explore additional sources to improve the monitoring of plant pest species (Tateosian et al. 2023) and to elucidate the effects of a changing distribution of a marine IAS on recreational anglers' and spear fishermen's perceptions (Sbragaglia et al. 2022). But as promising as these approaches are, they come with their own set of challenges and biases. For example, when working with digital data, it is important to consider the potential for misinterpretation (Ficetola 2013) as well as the ethical use and the safe keeping of potentially sensitive information (Correia et al. 2021).

European flounder is a flatfish species native to the coastal areas of Western Europe (Hemmer-Hansen et al. 2007). It is a catadromous species (Summers 1979) with plasticity in its utilization of marine, estuarine and freshwater habitats (Daverat et al. 2012; Le Pichon et al. 2014). European flounder was first officially reported in Icelandic waters in 1999 after a specimen was caught in the southwest of Iceland and reported to the Marine and Freshwater Research Institute of Iceland (Jónsson et al. 2001). European flounder has previously been introduced to the Great Lakes in North America via ballast water, but without established popula-

tions (Cudmore-Vokey and Crossman 2000; Ricciardi and MacIsaac 2000). In Iceland, reports of European flounder in the years following its first record, indicated a rapid spread and established populations in most parts of the country where it was predominantly encountered in estuarine and freshwater habitats (Kristinsson 2011; Ragnarsdóttir and Metúsalemsson 2020). Despite its current classification as potentially invasive (Gunnarsson et al. 2015), knowledge of its impacts remains scarce. Small-scale studies indicate competition with native salmonids in estuaries and rivers (O'Farrell 2012; Hlinason 2013) and European plaice (*Pleuronectes platessa*, Linnaeus, 1758) on estuarine nursery grounds (Henke et al. 2020). European flounder in Iceland most abundantly occupies similar habitats as native Atlantic salmon (*Salmo salar*, Linnaeus 1758), brown trout (*Salmo trutta*, Linnaeus, 1758) and Arctic char (*Salvelinus alpinus*, Linnaeus, 1758) which are all highly sought-after recreational species and potentially impacted by competition with this alien species (O'Farrell 2012; Hlinason 2013). Therefore, we identified the Icelandic recreational angling community as one of the main stakeholders affected by European flounder in Iceland. Angling is very popular amongst the public in Iceland with 31.5% of the population participating in angling activities according to a Gallup survey conducted in 2000 (Toivonen et al. 2000). However, it is also economically important. A recent study carried out by the Institute of Economic Studies at the University of Iceland (Institute of Economic Studies 2018) estimated that total expenditure on Atlantic salmon and brown trout angling permits in Iceland in 2018 was approximately 4.9 billion krona (37 million USD) and that the economic importance of angling had increased by 120% from an earlier study carried out in 2004 (Institute of Economic Studies 2004).

The aim of this paper is to use a combination of classical and novel techniques from the field of conservation culturomics to examine (1) stakeholder perceptions towards European flounder, a recently established alien fish in Iceland, and how these change over time, (2) differences in perceptions of recreational anglers operating in the species' native and introduced range, and (3) temporal changes in the public's interest in an IAS as well as how this topic has been communicated to the public. Overall, we hypothesize that (1) recreational anglers in Iceland will have a more negative perception of European flounder than recreational anglers in the native range, (2) perceptions in Iceland change over time, and (3) traditional and novel techniques provide similar insights into the perceptions of the specific stakeholder group towards an IAS, while these culturomics approaches will highlight a more neutral tone in the communication to the public. To achieve our aim and test these hypotheses, we administered online surveys to compare recreational anglers' perceptions on European flounder in Iceland and across its native range, as well as collected information on (1) how this species was communicated within the stakeholder group and to the public, as well as (2) the public's interest in this topic using internet search volume as a proxy.

Methods

Survey design and administration

To document and contrast the perception of Icelandic (introduced range) and western European (native range) recreational angling communities towards European flounder, we created three anonymous online surveys. All three surveys were centered around four likert-style questions: 1) „Do you think the flounder

could be an important recreational angling species?", 2) „Does the flounder have a negative impact on your angling experience?", 3) „Do you think the flounder has a negative impact on other species?", 4) „Do you consider the flounder a pest?" (Suppl. material 1). Other questions varied between surveys, as described below, and detailed in Suppl. material 1.

Two surveys were administered in Iceland to capture any changes in the perception of European flounder between 2019 and 2023. The first survey was administered in 2019 at the start of the first large-scale and interdisciplinary research project on European flounder in Iceland, which is still ongoing. This project engaged the Icelandic recreational angling community in the study of European flounder invasions in Iceland by creating awareness about European flounder as an alien species, examining potential social impacts experienced by recreational anglers and encouraging them to report sightings of the European flounder. While the research project was not intended as a continuous engagement effort, the positive feedback from the recreational angling community following these interactions (mainly via social media) indicated their interest in the topic and inspired the follow-up survey in 2023. The first survey was open for participation between October 2019 and June 2020. It included 17 questions to collect information on the participants' angling behavior, such as how often they fish annually and which species they target, as well as their experience with European flounder (Suppl. material 1). With frequent reminders, we shared the survey on the social media platform Facebook, frequently accessed by approximately 65% of the Icelandic population (Kemp 2024). Posts were made both on public pages of Icelandic research institutions as well as a specific group popular among Icelandic recreational anglers (Suppl. material 2). Additionally, the survey received coverage in a national Icelandic newspaper (Statistics Iceland 2024) in November 2019, encouraging participation (Jónsson 2019); Suppl. material 2). We received a total of 209 submissions. The second survey was administered in February 2023 as part of another project and, after close monitoring of the number of participants, was closed in March 2023 once a comparable number as the previous survey was reached. This survey contained nine questions of which 6 questions were relevant for this project and represented a subset of the first survey (Suppl. material 1). Again, we mainly advertised the survey via social media (Suppl. material 2). Additionally, the survey was covered in an episode of a popular Icelandic flyfishing podcast in March 2023 (Ólafsson and Harðarson 2023); Suppl. material 2). 193 people took part in this survey.

A survey aimed at recreational anglers in the European flounder's native range was administered in May 2021, again monitoring the participation numbers until the goal of ~200–220 was reached. Like the first survey conducted in Iceland, it included questions about the participants' angling behavior and their experience with European flounder. However, as recreational angling in the target countries is often conducted in coastal habitats where anglers are likely to encounter several flatfish species, a verification question was included to ensure the participants recognized the target species. In this verification question we asked participants to identify European flounder out of three pictures showing similar-looking flatfish species, European plaice (*Pleuronectes platessa*) and Common Dab (*Limanda limanda*). A verification question was assumed unnecessary for the Icelandic survey as recreational angling in Iceland conducted by the target group is mostly in freshwater habitats where European flounder is the only flatfish species present. We contacted

representative institutions for advice on how to best reach the respective recreational fishing communities. We then advertised the survey in Facebook groups popular among recreational anglers in Denmark, Faroe Islands, Finland, Germany, Norway, and Sweden (Suppl. material 2). Throughout the native range a total of 224 people responded to the survey. Informed consent was obtained from all individual participants included in the study. An introduction was included in all surveys, informing participants about the background and intent of the study as well as about the anonymous nature of the survey and the confidential treatment of the resulting data.

Extracting digital data on European flounder from different sources in Iceland

We conducted a systematic review of newspaper articles published between 1999 and 2022 available on timarit.is, a digital library aiming to provide access to newspapers and periodicals published in Iceland, the Faroe Islands and Greenland. We searched the database using the keywords 'flounder' as well as the two Icelandic terms for European flounder 'ósalúra' and 'flundra' and additionally allowed the search to include all grammatical declension of the Icelandic terms. Furthermore, we searched websites of popular newspapers in Iceland using the same keywords for any unaccounted articles (http://mbl.is, http://fiskifrettir.vb.is, http://skessuhorn.is, http://bbl.is/baendabladid). We manually checked all returned articles, excluding those that were not newspaper articles referring to European flounder in Iceland and manually extracted all text data. For the quantitative analysis we categorized all articles by whether they focused on European flounder or just mentioned it.

To explore mentions of European flounder in conversations on social media in Iceland, we opted for Facebook as target social media platform as this platform is used by over 60% of the Icelandic population (Suppl. material 2) and there was only a low number of tweets on Twitter mentioning European flounder in Iceland of which most were initiated by scientists. On Facebook we identified the group „Veiðidellan er frábær…" [The fishing passion is great...] as the most active group among the recreational angling community in Iceland based on the number of members (14.289 members as of 21.12.2022, Suppl. material 2) as well as personal recommendations of recreational anglers. We searched the group for any mention of European flounder in either original posts or comments to other posts from the establishment of the group in 2013 until the end of 2022 using the same search terms as for newspaper items. We manually extracted all returned conversations and categorized them as 'focused' conversations or 'mentions' when European flounder was part of the original post or was just mentioned in the comment section, respectively. We excluded all conversations that were initiated by the authors of this study from qualitative analysis. These posts were part of the ongoing research project on European flounder.

We used Google Trends to extract information on Google searches for the keywords 'flounder' and 'flundra' in Iceland (the keyword 'ósalúra' returned no results) between 2004–2023 using the gtrendsR package (Massicotte and Eddelbuettel 2022). Google Trends returns the Search Volume Index which represents normalized, non-real-time data going back as far as 2004 (Cebrián and Domenech 2024). Each data point is weighed against the total search queries for the given location and time frame and the overall results are then scaled to a range of 0 to 100 with 100 representing the maximum value (Google 2023). While Google

Trends returns relative data, Wikipedia pageview statistics provide raw counts for how often a Wikipedia page has been requested in a given time (Wikipedia 2023). We extracted the monthly page visits for the Icelandic Wikipedia page for European flounder between July 2015 and February 2023 using the pageviews package (Keyes and Lewis 2020).

Data preparation and analysis

Unless otherwise specified, all data processing and analysis were carried out in R (R version 4.2.2, R Development Core Team (2023).

Survey data

We reviewed all survey responses and excluded submissions where participants were either not from the target country or did not at least partly respond to the likert-style questions intended to capture their perception. Additionally, submissions to the native range survey were omitted when participants failed to recognize European flounder in the verification question (Suppl. material 1). In the likert-style survey question addressing the participants' perception, the response option 'I don't know' was graphically located to the side of response options indicating (dis) agreement. In our opinion, due to this graphical placement, we cannot say with certainty whether the respondent, by choosing the 'I don't know' option, intended to express a neutral perception (i.e. neither agree nor disagree) or a lack of knowledge. The responses to the likert-style perception question were graphed using the likert package (Bryer and Speerschneider 2016). For each likert item the polarization score was calculated using the agrmt package (Ruedin 2021), a metric ranging from 0 – 1, indicating to what degree the opinions expressed are separated along the range of ranked options, with 0 indicating all responses fall in the same category while 1 indicates that responses are evenly split between two opposing categories (van der Eijk 2001). We statistically compared responses to this question across all three surveys (Suppl. material 1 question 13 of survey A), question 4 of survey B), and question 10 of survey C). To test if perceptions had changed between the two Icelandic surveys, representing a pre and post evaluation of the same target group, we applied the Wilcoxon signed rank test, to test for a significant difference between data using the wilcox.test() function of the stats package (R Development Core Team 2023). To examine if perceptions differed between recreational anglers in Iceland and in European flounder's native range, we applied the Mann-Whitney U test, due to the independency of sampled groups, using the wilcox.test() function with the parameter 'exact' set to false. To explore potential relationships between the ordinal perception variables and selected variables we employed the Kendall Tau Rank correlation using the cor.test() function of the stats package. The explanatory variables included fishing activity, Atlantic salmon importance, brown trout and Arctic char importance and European flounder experience. The binary variable 'angling activity' represented the number of days participants spent fishing per season with the options of 'less than 10 days' (pooled options '6–10 days', '1–6 days', and 'I don´t fish') and '10 or more days'. The three native salmonids as target species were split into two variables with Atlantic salmon in one and brown trout and Arctic char combined in the other to reflect the differences in the monetary value of the angling licenses. While the underlying data for the

previous three variables were collected across all three surveys, questions regarding the participants' previous experience with European flounder making up the fourth exploratory variable, were only included in the first Icelandic and the native range survey. This variable summarized the participants' responses to whether they are documenting and/or keeping European flounder catches, specifically targeting European flounder and having cooked and/or consumed European flounder.

Text mining

To qualitatively explore stakeholders' perceptions and media cover of European flounder in Iceland since its arrival, we analyzed the content of all extracted newspaper articles, Facebook conversations as well as participants comments in the Icelandic surveys. The timeline of the collected data was arbitrarily split into three periods. We defined the first threshold as '2013' when the targeted Facebook group was first established. The second threshold was set at 'October 2019' marking the beginning of the research project on European flounder in Iceland, and the adjacent outreach to the public and recreational angling community. This outreach included the active engagement of stakeholders in research activities and updating them about the outcomes as well as opportunistic coverage of the research on national television (Ólafsdóttir 2021), newspapers and a podcast. This approach allowed us to not only explore potential changes in how European flounder has been communicated to and by the public, but to furthermore compare between sources in each time period, where applicable. For each period and data source we combined all text data, resulting in the six individual text corpora 'Newspapers until 2013', 'Newspapers between 2013 and October 2019', 'Newspapers since October 2019', 'Facebook conversations between 2013 and October 2019', 'Facebook conversations since October 2019' and 'Survey comments since 2019'. To create uniform corpora, we translated all sentences extracted in English into Icelandic as this was the most prevalent language across all text data.

Prior to analysis, the text data was preprocessed, including lower casing, the removal of stop words, numbers, and punctuation as well as the stemming of words (Sumathy and Chidambaram 2013). While there is a wide range of tools available to conduct these steps for English texts using R functions, resources are scarce for the Icelandic language. We therefore developed a manual approach for the preprocessing of our data. In a first step, we manually removed punctuation, numbers, and capital letters from all corpora. Then, we excluded Icelandic stop words based on two published lists (Jasonarson 2019; Friðriksdóttir and Jasonarson 2021). For the remaining words we created a list of word frequencies across all corpora which returned ~12 k unique words. To facilitate manual processing, we excluded all words with a frequency of less than five across all text data, reducing the number of individual words to 1667. This step was conducted under the assumption that words with the lowest frequencies are unlikely to have a significant effect on the overall results. From the remaining list we identified and removed additional stop words including auxiliary verbs, adverbs, given names and numbers. This resulted in 1436 words which were then translated into English. In replacement of automatic stemming, we adjusted the words manually by 1) removing (un)specific articles in translations; 2) exchanging all mentioned species' names with their respective scientific names; 3) reducing nouns and verbs to their common stem where applicable; and 4) combining adjective degrees, different tenses, active and passive

voice, as well as singular and plural nouns. After implementing the translations and adjustments, we transformed all corpora using the tm package (Feinerer et al. 2008; Feinerer and Hornik 2023). To be adequately translated, some Icelandic terms required 2–3 words in English. To preserve these multiple-words translations as unique units, we connected the words visually as follows:

Icelandic: Vesturland **->** ***English:*** west Iceland -> ***in corpora:*** west.Iceland

All translations and stop word identifications were conducted by a native Icelandic speaker. To further ensure the quality of the preprocessing, all cases of difficult adjustments were reviewed by multiple authors. While we are confident to have achieved high quality results in the manual preprocessing, we recognize that some sources of errors may remain due to the subjective nature of manual approaches.

Topic and word frequency analysis

To exclude rare words from further analysis, all words with a frequency of less than five within a corpus were omitted from that specific, preprocessed corpus. Topic analysis was conducted based on Latent dirichlet allocation (LDA) using the LDA() function of the topicmodels package (Grün and Hornik 2011, 2023). The LDA algorithm is mainly guided by the two principles that documents consist of a mix of topics and that topics are made up by a mix of words. This analysis requires a predefined number of topics (k). Defining the ideal k using the FindTopicsNumber() function of the ldatuning package (Nikita 2020) remained unsuccessful, returning nonsensible results. Therefore, we continued rerunning the analysis using decreasing numbers of k until clear and distinct topics were revealed. The analysis returned both per-topic-per-word probabilities (β) as well as per-document-per-topic probabilities (γ). For each topic we defined a title based on the 10 words with the highest β-values. Based on the γ-values, we then calculated the topic composition for each of the six corpora. We generated a list of the most frequent terms for each text corpus from the transformed text data. We determined the frequency threshold for each corpus arbitrarily with the requirements that a maximum of 10 terms is retained and that all terms with the same frequency were omitted when including all of them would have increased the total terms retained to more than 10.

Results

Stakeholder perceptions of European flounder based on online surveys

For the first Icelandic survey, 205 out of 209 submissions were included in the analysis. 72% of these participants stated that they fish over 10 days annually, mostly in western Iceland with 50% reporting the southwest of Iceland and 26% the northwest. While 39% of the participants (very) often targeted Atlantic salmon, brown trout and Arctic char were (very) often targeted by 69% and 66% of the participants, respectively, (Suppl. material 3). In the 2023 Icelandic survey, 191 out of 193 responses were retained for analysis, of which 27% took part in the first survey, 30% were not sure about their previous participation, and 43% took part for the first time. 71% of participants fished for more than 10 days annually, of which 38%, 57% and 64% targeted Atlantic salmon, brown trout and Arctic char

(very) often, respectively. We originally received 224 responses in the native-range survey of which 20 responses were omitted due to either incomplete answers or the respondents not fishing in the European flounder´s native range. An additional 50 answers were excluded due to failing to recognize European flounder in the verification question, leaving 154 answers for analyses. 91% of the participants considered for analysis were fishing 10 or more days annually. Fishing was conducted in nine countries with most participants fishing in Germany (36%) and Denmark (34%), followed by Norway (13%) and Sweden (13%). Atlantic salmon was (very) often targeted by 15% of the participants, and brown trout and Arctic char by 31% and 6%, respectively. When asked about additional species targeted, participants listed 50 different species. Atlantic cod (*Gadus morhua*, Linnaeus, 1758) was most often named, followed by northern pike (*Esox lucius*, Linnaeus, 1758) and European perch (*Perca fluviatilis*, Linnaeus, 1758) (Suppl. material 3).

Participants of the first Icelandic survey generally disagreed that European flounder could have a value as recreational species (90% of expressed opinions). 79% agreed that European flounder had a negative impact on their own angling experience, 96% agreed that European flounder negatively affects other freshwater species, and 88% considered European flounder as a pest (Fig. 1A). Across all statements the polarization score ranged from 0.1068 on European flounder value as recreational target species to 0.2626 on European flounder's negative effect on the angling experience (Suppl. material 4). The only significant correlation was a positive one between the importance of Atlantic salmon for participants and a strong agreement on European flounder's negative impact on the participants' angling experience (0.1778, p=0.00695, Suppl. material 5).

While a similar pattern of perceptions was observed in the follow-up survey in 2023, there was a statistically significant change towards less negative perceptions in the responses to all statements (Fig. 1, Suppl. material 6). In 2023, 86% of the participants expressing an opinion did not see a potential value of European flounder in recreational angling (Fig. 1B). 63% agreed that European flounder had a negative impact on their angling experience, 89% agreed that European flounder negatively affects other freshwater species, and 67% consider European flounder as a pest. When only including the 27% of participants indicating their participation in the previous survey, the change remained significant for all questions apart from question 1 addressing the potential recreational importance of European flounder. The polarization scores were generally higher in the second Icelandic survey and ranged from 0.1749 regarding European flounder's recreational value, to 0.4061 regarding the species' impact on the angling experience (Suppl. material 4). Here, a significant negative correlation was detected between the importance of brown trout and Arctic char as a targeted species and the agreement that European flounder is a pest (-2.4702, p = 0.0135; Suppl. material 5).

Perceptions among participants of the native range survey differed significantly from perceptions in Iceland (Suppl. material 6), with 91% of those expressing an opinion, agreeing that European flounder could be an important recreational angling species (Fig. 1C). However, 95% disagreed that European flounder is negatively impacting their angling experience, 83% disagreed that there is a negative impact on other freshwater species, and 98% disagreed that European flounder is a pest (Fig. 1C). The lowest polarization score (0.0622) was on whether European flounder is considered a pest and the highest (0.2476) regarding European flounder's impact on other species (Suppl. material 4). Participants with more prior experience with European flounder were more likely to agree that European flounder

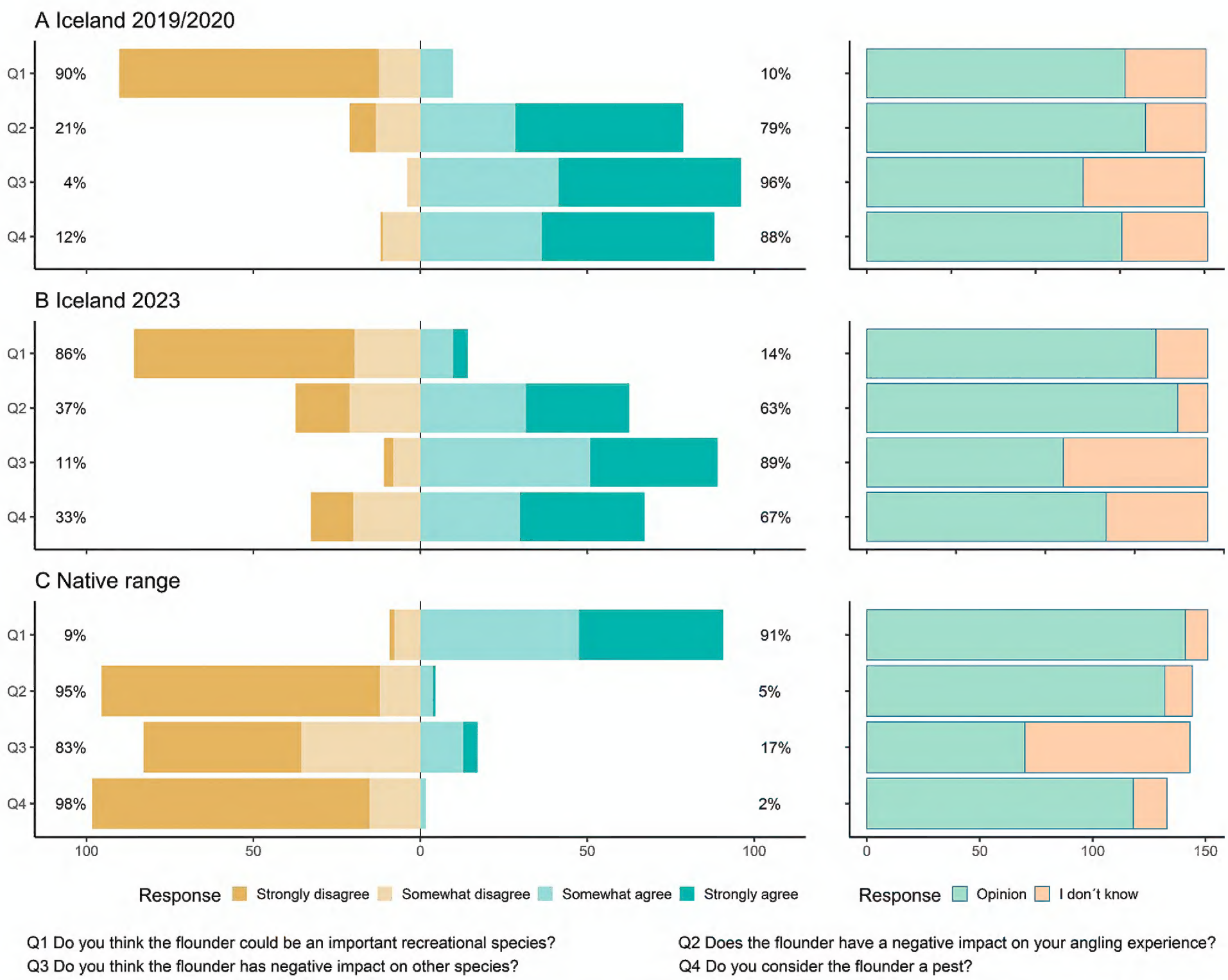
A Iceland 2019/2020
Q1 90% 10%
Q2 21% 79%
Q3 4% 96%
Q4 12% 88%
B Iceland 2023
Q1 86% 14%
Q2 37% 63%
Q3 11% 89%
Q4 33% 67%
C Native range
Q1 9% 91%
Q2 95% 5%
Q3 83% 17%
Q4 98% 2%
100 50 0 50 100
0 50 100 150
Response Strongly disagree Somewhat disagree Somewhat agree Strongly agree
Response Opinion I don´t know
Q1 Do you think the flounder could be an important recreational species?
Q2 Does the flounder have a negative impact on your angling experience?
Q3 Do you think the flounder has negative impact on other species?
Q4 Do you consider the flounder a pest?

Figure 1. Survey participants' perception towards European flounder based on their responses to the surveys. The likert graphs show the responses of participants to rating their agreement (Strongly disagree – Strongly agree) to the questions. Barplots on the right plot indicate the number of participants that expressed an opinion on the question and the number of participants that answered, 'I don't know'. The results are given for the surveys conducted in Iceland in 2019/2020 (**A**), in Iceland in 2023 (**B**) and in European flounder's native range (**C**).

could be recreationally valuable (τ = 3.2528, p = 0.00114), but less likely to agree that European flounder negatively impacts their angling experience (τ = -3.5273, p = 0.0004), negatively impacts other species (τ = -2.0508, p = 0.0403) or that European flounder is a pest (τ = -2.469, p = 0.01355) (Suppl. material 5).

Quantitative representation of European flounder in Icelandic digital sources

The systematic review of newspaper articles returned 99 articles published in Iceland between 2000 and 2022 referring to the European flounder (Fig. 2A). 35 articles were focused on European flounder in Iceland while 64 mentioned the species in relation to other topics. For most years there was a mix of focused and mentioning reporting. Generally, the reporting increased over the first years following the initial documentation of European flounder in Icelandic waters, reaching a first peak in 2005 with seven articles. Following the highest peak in 2011 with 17 articles, the reporting decreased over the following years until 2017 when no article was published featuring the European flounder. Following the on-

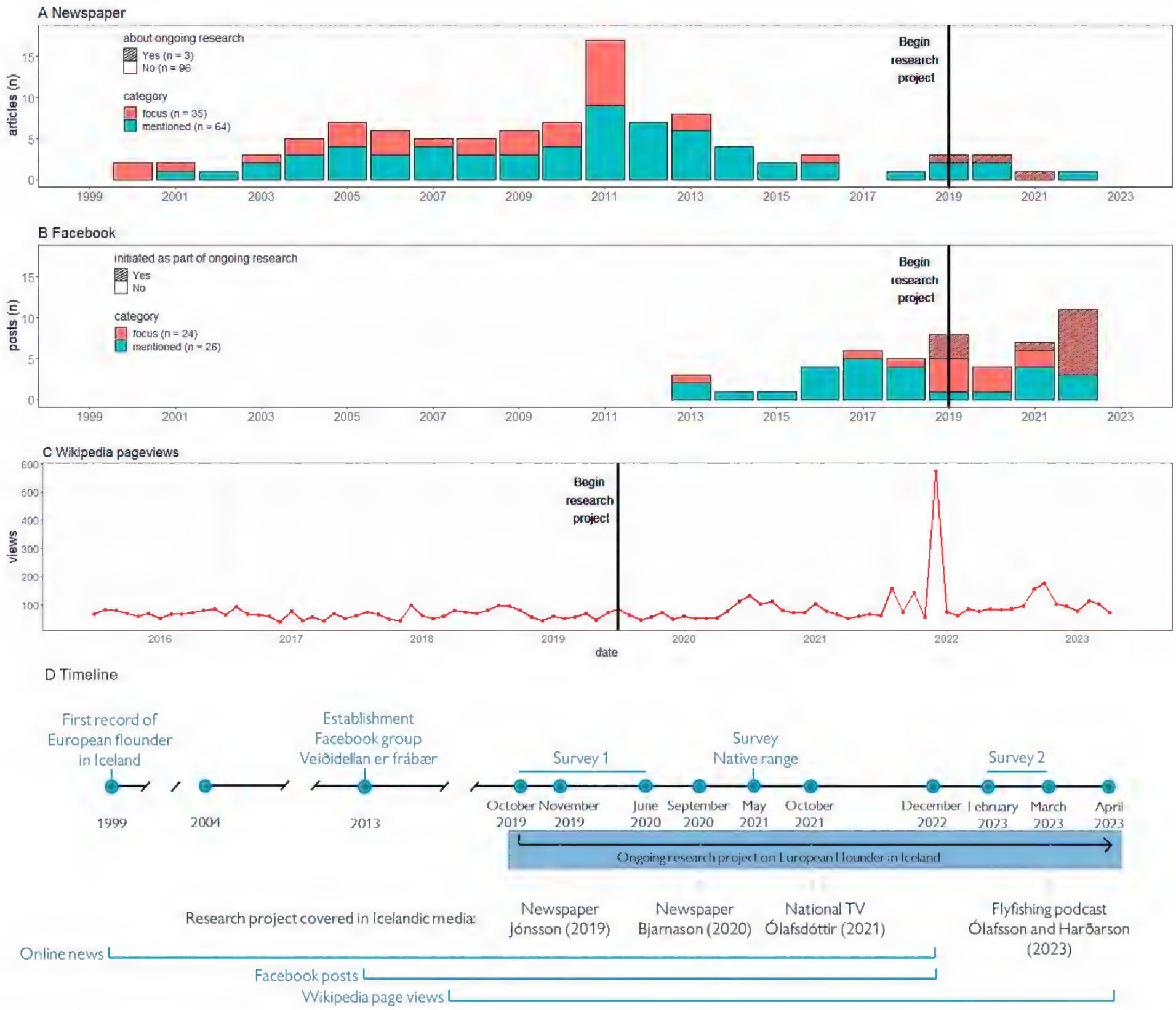

Figure 2. European flounder's presence in different media platforms as well as in search queries since 1999 **A** newspaper articles published in Iceland between 1999 and 2022 accessible on timarit.is **B** conversations in public Facebook group for recreational angling community in Iceland that either focus on or mention European flounder **C** monthly number of views of Icelandic Wikipedia article 'Flundra' between July 2015 and February 2023 **D** timeline indicating the timeline of this study, the timeline covered in the digital data as well as important dates such as the beginning of the ongoing research project on European flounder and the dates of the research covered in Icelandic media.

set of the current research the number of newspaper articles increased again with nine articles published between 2018 and 2022. Included in these numbers are two articles published in 2019 and 2020 that specifically reported on the current research (Jónsson 2019; Bjarnason 2020). We extracted 50 conversations from the target Facebook group that were posted between 2013 and 2022 (Fig. 2B). In 24 of these conversations, the original post referred to European flounder (focus), while 26 conversations mentioned European flounder only in the comments (mention). Prior to 2019, 17 conversations were classified as a mention. Since 2019, 30 conversations were recorded of which 9 were classified as a mention. Out of the conversations recorded since 2019, 12 (2019 = 3, 2020 = 0, 2022 = 8; Fig. 2B) were initiated by the authors of this study. These posts were created to inform the group about ongoing research activities on European flounder as well as to encourage survey participation. Their content was excluded from qualitative analysis to reduce potential biases.

Qualitative communication of European flounder in Icelandic (social) media content and survey comments

Across all text data, we detected three distinct topics reflecting the context in which European flounder was mentioned. Based on the ten words with the highest β values, we termed these topics 'Arrival and spread of European flounder in Iceland', 'General monitoring/surveying', and 'European flounder in recreational angling in Iceland' (Fig. 3). The main topic identified in newspaper articles published before 2013 was 'Arrival and spread of European flounder in Iceland'. Between 2013 and October 2019, the topic 'General monitoring/surveying' was most frequent among newspaper articles while it was 'European flounder in recreational angling in Iceland' in articles published since October 2019. In all analyzed Facebook conversations as well as the survey comments, the most common topic was 'European flounder in recreational angling in Iceland', while 'arrival and spread of European flounder' was least frequent. The survey comments were likely influenced by both the topic of the survey as well as its introduction to potential participants and can therefore not be considered objective. The results of the topic analysis remained similar when the survey comments were omitted, and we decided to include them in the results.

The frequency analysis returned the most frequent terms used in each source and time frame. A total of 23 unique terms were identified (Fig. 4). While 11 of these terms were corpus-specific, 12 recurred in two or more corpora. The most prominent terms, documented across all six corpora, were 'catch' and '*Platichthys flesus*'. The relative importance of the term '*Platichthys flesus*' fluctuated between corpora (Fig. 4). In the newspaper articles published before 2013, European flounder was the third most frequent term following 'catch' and 'year'. While it dropped down to rank 8 in the newspaper articles published between 2013 and October 2019, it was the most frequently used term in newspapers since October 2019. Across both Facebook and survey comments corpora, European flounder remained the most frequent word used, with percentages ranging from 21% for Facebook 2013 – October 2019 to 35% in the survey comments.

Public interest in *P. flesus* based on Google Trends and Wikipedia

The Google Trends analysis initially returned results indicating peaks of public interest in both the English (flounder) and the Icelandic (flundra) them throughout the chosen time frames. However, repeated runs of the analysis did not reproduce those results and showed remarkable differences both in the number of peaks and their timing. Because of these inconsistencies the Google Trends results are not included in any conclusions of this study. Wikipedia pageviews on the other hand produced reliable and reproducible results. Before October 2019 (i.e., the beginning of the research project on European flounder), the monthly views of the Icelandic Wikipedia page for European flounder stayed below 100 with slight fluctuations (Fig. 2C). Since the start of the research project, three time periods were recorded where the number of monthly page views appear elevated (>110). These include the periods June to September 2020, August to December 2021, as well as September to October 2022. Within the period of August to December 2021, there were three distinct spikes recorded with the strongest one exceeding 550 views in December 2021, while for the other two periods pageviews appeared generally elevated.

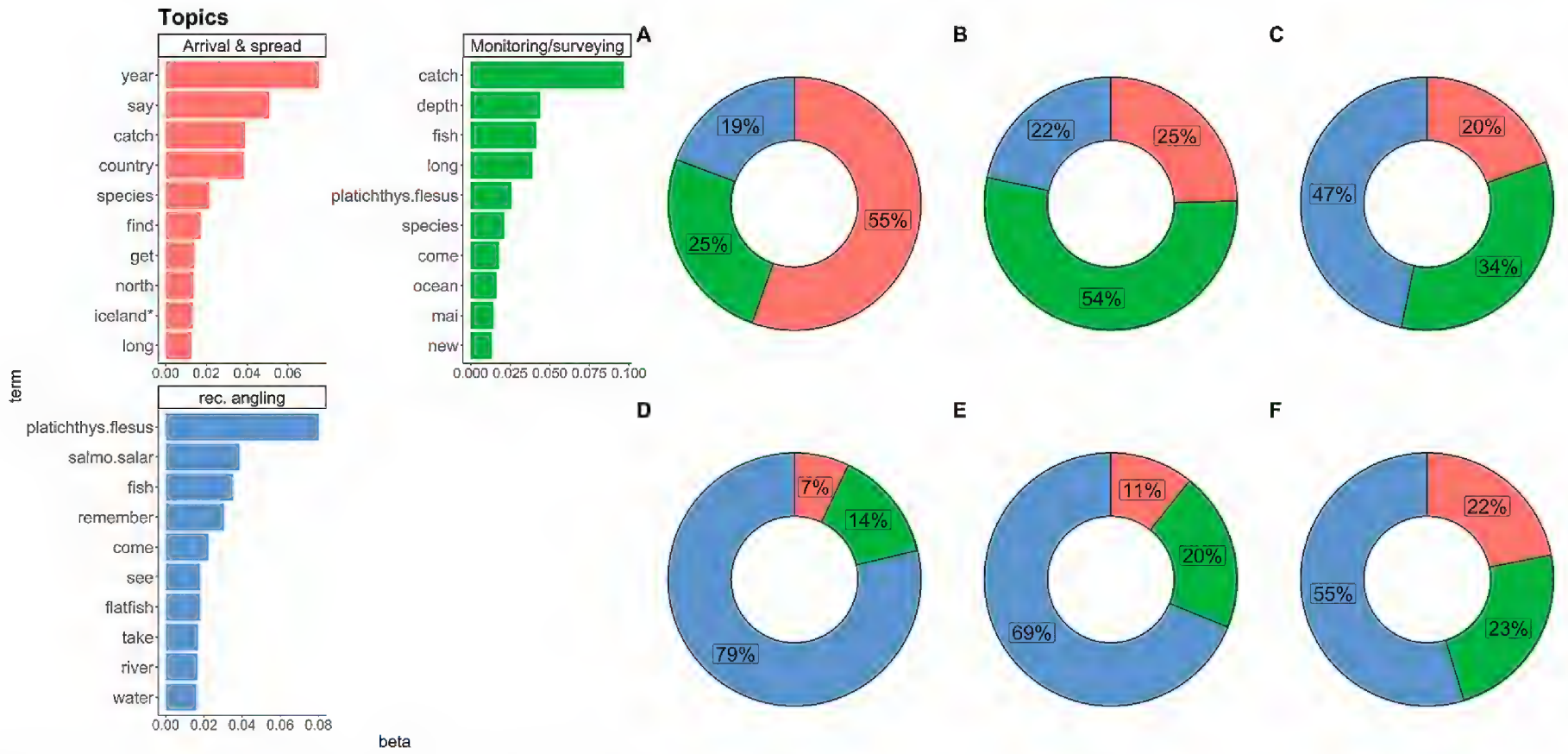

Figure 3. Identified topics newspaper articles, Facebook conversations and survey comments about European flounder. The three identified topics 'Arrival and spread of European flounder' (pink), 'General Monitoring/surveying' (green) and 'European flounder in recreational angling' (blue) and their respective 10 most frequent words are displayed in barplots on the left-hand side. The calculated topic composition for each of the six corpora are pictured in donut plots on the right-hand side **A** newspaper before 2013 (n = 72 articles) **B** newspaper 2013 – Oct. 2019 (n = 20 articles) **C** newspaper since Oct. 2019 (n = 6 articles) **D** facebook 2013 – Oct. 2019 (n = 25 posts) **E** facebook since Oct. 2019 (n = 13 articles) **F** survey comments (n = 22 comments)

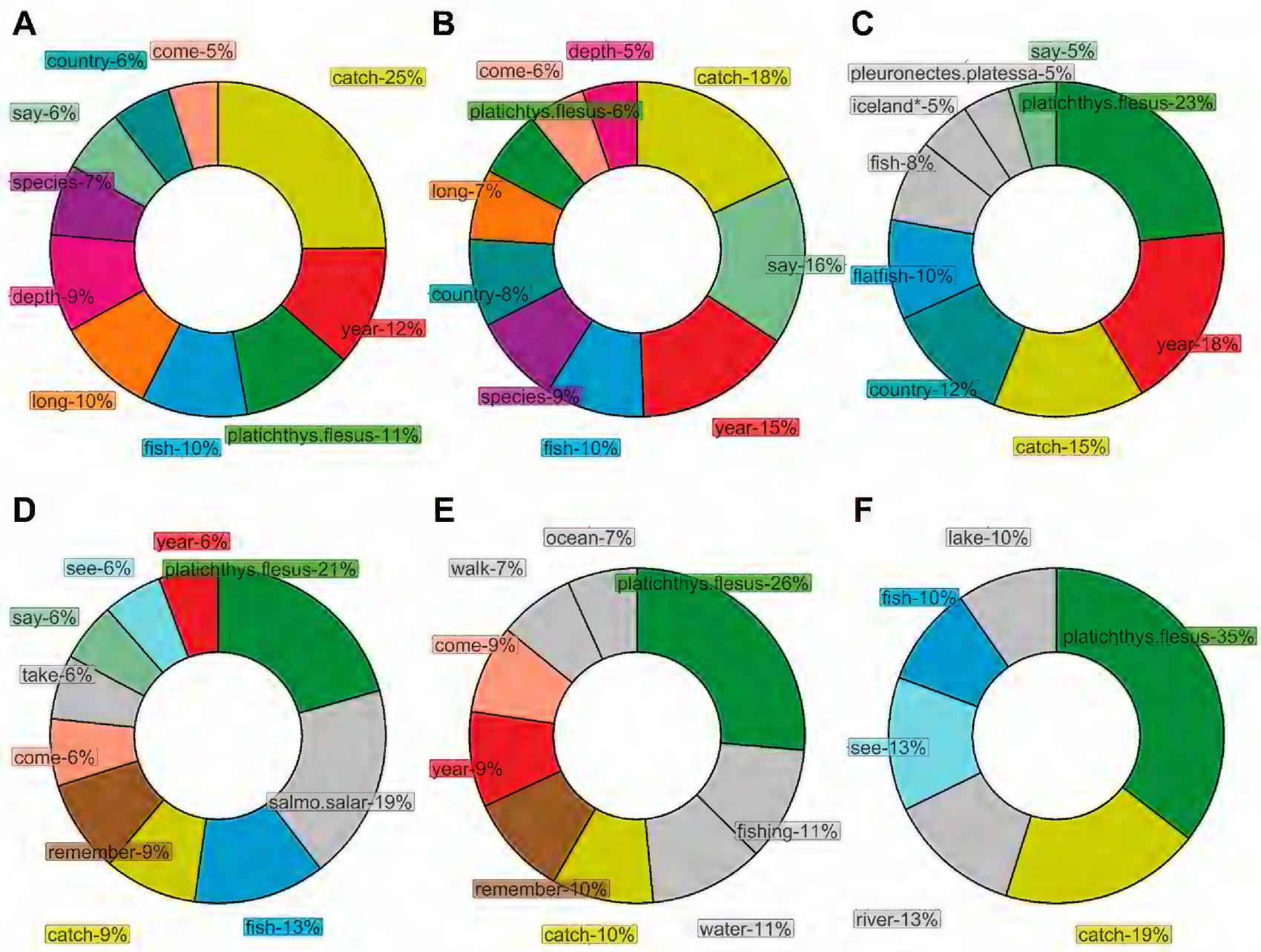

Figure 4. The most frequent terms identified for each corpus. The donut graphs display up to ten terms where corpus-specific terms are in grey and recurring terms are highlighted with individual colors **A** newspaper before 2013 (n = 72 articles) **B** newspaper 2013 – Oct. 2019 (n = 20 articles) **C** newspaper since Oct. 2019 (n = 6 articles) **D** facebook 2013 – Oct. 2019 (n = 25 posts) **E** facebook since Oct. 2019 (n = 13 articles) **F** survey comments (n = 22 comments)

Discussion

In this study we examined stakeholders' perceptions towards alien European flounder in Iceland using both traditional surveys and novel culturomics approaches. Our results from traditional surveys show that Icelandic recreational anglers have negative perceptions towards the European flounder, which stands in strong contrast to the positive perceptions documented among recreational anglers in the species' native range. However, the results we obtained by using novel culturomic approaches (Ladle et al. 2016) did not indicate similar negative perceptions in how the flounder has been communicated to the public in Iceland, or how it was discussed within the targeted stakeholder group of recreational anglers.

Stakeholder perceptions towards European flounder in Iceland and its native range

The survey results showed that recreational anglers in Iceland had strong opinions about European flounders' negative impact on their angling experience, on native species and, overall, considered it a pest. On the other hand, the results of the survey we distributed in the European flounder's native range showed that recreational anglers consider the species to have a recreational value and no negative effects. In its native range, European flounder is considered a popular sportfish especially for beginners as it is valued for its availability in shallow waters and its readiness to bite (Skerritt 2010). Perceptions towards alien species can be influenced by a variety of factors (Shackleton et al. 2019b). One possible explanation for this great difference in perceptions between invaded and native range could be that the strongly negative perceptions of recreational anglers in Iceland are likely to be less driven by the general characteristics of the species but rather its status as an alien species and its perceived threat to native species. Although research on the impacts of European flounder on native salmonids (O'Farrell 2012; Hlinason 2013) is limited, the overlap with this alien species could be perceived as a threat, especially considering that the Arctic char population in Iceland has been continuously decreasing since 2000 (Guðbergsson 2014), which coincides with the arrival of European flounder (Jónsson et al. 2001).

Personal experience with an introduced species as well as emotional connectedness to impacted native species or ecosystems can drive perceptions (Fischer and van der Wal 2007; Kueffer 2013). The survey results indicate that Icelandic recreational anglers perceive a negative impact by the presence of European flounder while targeting more sought-after species, such as Atlantic salmon or brown trout. Considering the popularity of recreational angling in Iceland (Toivonen et al. 2000), anglers are likely to be emotionally attached to the fishing environment and its native species, therefore the European flounder is perceived as a threat even in the absence of scientific research on its ecological impacts. Additionally, perceived economic threats can influence attitutes towards alien species (Verbrugge et al. 2013). Especially those stakeholders with financial interest, such as river owners, could fear that the presence of European flounder could influence license purchases and therefore cause financial damage.

The follow-up survey conducted in 2023 documented a significant change in perception. Most notably that 1) less people consider the European flounder as a pest and 2) less people perceive it to have a negative impact on their angling experience. However, the available data does not enable us to pinpoint the specific driver of these

change in perceptions. One potential explanation is that the continuous engagement with the recreational fishermen, mostly via social media, led to an increased media coverage. The research was covered across multiple media sources, spanning newspaper articles (Jónsson 2019; Bjarnason 2020), national TV (Ólafsdóttir 2021), and a podcast interview (Ólafsson and Harðarson 2023). Through this increased exposure, stakeholders might have gotten more familiar with the presence of European flounder in the Icelandic ecosystem. While this has not increased the species' recreational value in their eyes, it decreased their perception of the European flounder as a threat to their angling activities. This is in line with previous research suggesting that in addition to prolonged exposure, awareness and knowledge among the public and stakeholders can shape perceptions (e.g. (Garcia-Llorente et al. 2008; Sharp et al. 2016; Courchamp et al. 2017) which in turn is influenced by how an issue is communicated by the scientific community (Nisbet and Scheufele 2009). Overall, little attention has been paid to the socio-economic impacts of alien species in Iceland (Kourantidou et al. 2022). This study therefore provides an important addition to our knowledge of human aspects and, especially, the social impacts of an alien species in Iceland.

Is the documented perception of stakeholder groups reflected in digital data?

Our methodological comparison indicated a mismatch between traditional and novel tools applied to explore perceptions towards European flounder in Iceland. When directly interacting with the targeted stakeholder group using online surveys, we documented highly negative perceptions. However, when we applied novel approaches to explore how European flounder has been communicated within the recreational angling community on social media, the most frequent words cannot be linked to a negative perception. The neutral tone in these communications is surprising. As most survey participants were targeted through the specific Facebook group, we expected to see the strongly negative perceptions captured in the surveys to at least be partially reflected in the results of the social media conversations. The common words and neutral topics notable in the newspapers are less surprising as they may just reflect the contrasting perceptions of the public and the stakeholders towards the European flounder. That is, the application of novel tools enables us to contrast potential differing perceptions between the general public and specific stakeholder groups.

Such comparative studies are needed to address the validity of results obtained applying conservation culturomics (Ficetola 2013; Correia et al. 2021; Jarić et al. 2021). Here, the case study of European flounder in Iceland represents a valuable opportunity for such methodological comparison to detect stakeholders' perceptions towards an alien species. Based on the surveys we have a thorough understanding of prevailing perceptions among the recreational angling community and due to the advantageous characteristics of questionnaires, especially the use of fixed answers and questions (Newing 2011), we were able to quantify them. Despite some great advantages, these traditional tools also come with certain limitations and shortcomings (Newing 2011). Factors such as limited geographic range and the potential bias of researchers as well as participants potentially influence the results (Newing 2011; Di Minin et al. 2015). However, we are confident that by advertising the online surveys not only via social media but also via channels such as newspaper articles and a podcast, we have captured the perception of a representative group of participants across the surveys conducted in 2019 and

2023. At the same time we have a holistic overview of how the arrival and spread of European flounder in Iceland has been communicated to the public via newspaper articles and within the stakeholder group over the past decade based on the data retrieved from a representative Facebook group.

Several factors could have contributed to the detected mismatch. One factor is a potential language bias that arises when utilizing textual data that is predominantly in Icelandic, a language currently spoken by less than 500.000 people globally. The use of non-English, non-major languages remains a challenge to these novel approaches (Funk and Rusowsky 2014; Ladle et al. 2016). It would have been preferential to apply sentiment analysis, a culturomics tool that has been increasingly used to highlight the perceptions and attitudes towards a specific topic across various forms of media (Lennox et al. 2020). As tools to conduct sentiment analysis on Icelandic texts are not yet available, we chose alternative approaches based on word frequencies. Both the unavailability of sentiment analysis of Icelandic texts as well as the translation work described previously could have contributed to the absence of negative perceptions in newspaper articles and social media conversations. Another potential factor is the scale of the case study, as Iceland is a small country. While this enabled us to capture a holistic picture of the communication of European flounder, the amount of data produced since the first documentation of European flounder might not have been sufficient to adequately capture the perceptions of the public and/or specific stakeholder groups through the analyses of digital data. Our results suggest that in the case of small-scale study systems, novel culturomics tools can provide valuable information, but should be applied complementary to traditional tools that directly interact with the target group to document prevailing perceptions and attitudes.

Linking communication to peaks in the public‘s interest in European flounder

Our results show fluctuations in the public´s interest in European flounder since its arrival in Iceland. While the term '*Platichthys flesus*' was among the three most frequent terms used in newspaper articles until 2013, a timeframe in which European flounder became increasingly present in Icelandic waters, it became much less frequently used in articles published between 2013 and October 2019. This development is in line with the transient nature of the public's attention towards conservation issues and many other global issues (Jarić et al. 2023), especially once the novelty of a topic wears off. However, following October 2019, the term became the most widely used term in the newspaper articles, potentially driven by the increased research and communication activities.

Public interest in Iceland, based on the temporal development of the number of times the Icelandic Wikipedia page for European flounder has been accessed, showed some distinct fluctuations over time that partially coincided with the current research being covered in Icelandic media. Both the newspaper article in September 2020 (Bjarnason 2020) as well as the coverage on national TV in October 2021 (Ólafsdóttir 2021) were followed by short-term elevations in public interest. Additionally, a prominent peak was documented in December 2021, following an episode of the flyfishing podcast *Hylurinn* where European flounder was discussed in an interview with a scientist at the Icelandic Marine and Freshwater Research Institute (MFRI) (Ólafsson and Harðarson 2021). While we could only identify potential triggers for a subset of the short-term peaks, these results indicate that public

interest can be triggered by a variety of different platforms. This suggests that communication strategies could benefit from incorporating different communication platforms catering to different groups. By understanding the dynamics of the public‘s attention, we can not only learn how to trigger periods of increased interest, we can furthermore try to predict windows of opportunity where communication and outreach campaigns are likely to be most effective (Fink et al. 2020; Jarić et al. 2023).

A popular tool to approximate public interest in a certain topic is Google Trends (Nghiem et al. 2016). However, in the case of European flounder in Iceland, Google Trends did not provide reliable results. The inconsistencies occuring between samplings are driven by the underlying characteristics of the analysis utilized by Google Trends, where only a subset of the total search queries are used to provide the Search Volume Index for the specific keywords and the subset used changes from day to day (Cebrián and Domenech 2024). These inconsistencies can be addressed for instance by drawing the average of repeated samplings which has been successfully applied in studies, indicated by cross-correlations of 79 – 99% between samplings (D'Amuri and Marcucci 2017; Cebrián and Domenech 2022). But the simulations carried out by Cebrián and Domenech (2024) further highlight that terms of low popularity produce a greater amount of variability, which would require a large number of repeated samplings to reduce the noise. European flounder in Iceland likely represents a low-popularity term, explaining the vast differences detected in the Google Trends results. Overall, this further highlights the limitations of conservation culturomic approaches in regards to small-scale studies.

Conclusion

Our results are consistent with the view that the social dimensions of biological invasions are crucial to obtain a holistic understanding of the impacts of alien species. The results of the current study highlight that perceptions of a species can profoundly differ between invaded and native range. While an alien species is perceived as highly negative in its introduced environment, the same species can be highly valued for its traits by a comparable stakeholder group in its native range. Furthermore, we show that stakeholders' perceptions and public interest in an alien species can fluctuate over time. Identifying potential triggers of these changes can represent a valuable lesson to design future outreach campaigns to increase public awareness and encourage the public to report their observations. In turn, those observations can contribute to early detections and monitoring of alien species. Finally, our study showcases the benefits of utilizing culturomics but also highlights limitations when applying some of these approaches on non-English text data in small countries.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Survey questions included in the three administered surveys

Authors: Theresa Henke, Ana Novoa, Hlynur Bárðarson, Guðbjörg Ásta Ólafsdóttir

Data type: pdf

Explanation note: A) Iceland 2019/2020, B) Iceland 2023, and C) native range.

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Link: https://doi.org/10.3897/neobiota.93.117200.suppl1

Supplementary material 2

Statistical information on Facebook groups and media platforms

Authors: Theresa Henke, Ana Novoa, Hlynur Bárðarson, Guðbjörg Ásta Ólafsdóttir

Data type: pdf

Explanation note: Statistical information on Facebook groups and media platforms utilized to advertise surveys among recreational anglers in Iceland as well as institutions that were contacted in relation to advertising the survey throughout the European flounders´ native range.

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Link: https://doi.org/10.3897/neobiota.93.117200.suppl2

Supplementary material 3

Descriptive statistics for the three administered surveys Iceland 2019/2020, Iceland 2023 and Native range 2021

Authors: Theresa Henke, Ana Novoa, Hlynur Bárðarson, Guðbjörg Ásta Ólafsdóttir

Data type: pdf

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Link: https://doi.org/10.3897/neobiota.93.117200.suppl3

Supplementary material 4

Polarization scores for the responses to the four likert-style questions across all three surveys

Authors: Theresa Henke, Ana Novoa, Hlynur Bárðarson, Guðbjörg Ásta Ólafsdóttir

Data type: pdf

Explanation note: Low polarization scores indicate that responses are skewed to one side while a higher score suggests a more even distribution in the responses ranging from “strongly disagree” to “strongly agree”.

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Link: https://doi.org/10.3897/neobiota.93.117200.suppl4

Supplementary material 5

Results of the Kendall Tau Rank correlation for all surveys

Authors: Theresa Henke, Ana Novoa, Hlynur Bárðarson, Guðbjörg Ásta Ólafsdóttir

Data type: pdf

Explanation note: We tested for potential relationships between the variables describing the perception of participants towards European flounder and selected explanatory variables. Significant results are highlighted in bold.

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Supplementary material 6

Statistical comparisons of participants responses to the likert-style questions between surveys

Authors: Theresa Henke, Ana Novoa, Hlynur Bárðarson, Guðbjörg Ásta Ólafsdóttir

Data type: pdf

Explanation note: Wilcoxon rank test and Mann Whitney U test were employed to compare responses between the two Icelandic surveys and between the native range and Icelandic surveys, respectively.

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